SEISMIC HAZARD ZONE REPORT 106

SEISMIC HAZARD ZONE REPORT FOR THE SLEEPY VALLEY 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

2003

DEPARTMENT OF CONSERVATION
California Geological Survey

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EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Sleepy Valley 7.5-Minute Quadrangle, Los Angeles County, California. The map displays the boundaries of zones of required investigation for liquefaction and earthquake-induced landslides over an area of approximately 43 square miles at a scale of 1 inch = 2,000 feet.

The Sleepy Valley Quadrangle lies in northern Los Angeles County 11 miles west of Palmdale and 35 miles northwest of the Los Angeles Civic Center. The east-trending crest of the Sierra Pelona crosses the center of the quadrangle. Bouquet Canyon, part of Bouquet Reservoir and Leona Valley are on the north side of the mountain crest. Mint Canyon and Sierra Pelona Valley are on the south. The San Andreas Fault Zone lies within Leona Valley in the northeastern corner. The highest point (5,187 feet) in the quadrangle is Mount McDill on the crest of the Sierra Pelona. The lowest point, below 2,160 feet, is in Mint Canyon in the southwestern corner. The Angeles National Forest covers about 50 percent of the quadrangle. Parcels of private land are scattered within the forest, especially along Bouquet Canyon. The communities of Leona Valley, Sleepy Valley, and Agua Dulce and all of the private land in the quadrangle are unincorporated. Land use includes ranching, rural residential areas, and recreation. Access to the region is via the Sierra Highway on the south, Bouquet Canyon Road in the center, and Elizabeth Lake – Pine Canyon Road on the north.

The map is prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years.

In the Sleepy Valley Quadrangle the liquefaction zone is concentrated in areas where young Quaternary alluvial deposits and shallow ground water occur within much of Leona Valley and numerous canyon bottoms. Large old landslides occur within the uplifted, deformed and foliated schistose rocks of the Sierra Pelona. Steep terrain also contributes to an earthquake-induced landslide zone that covers about 13 percent of the evaluated portion of the quadrangle.

How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

Paper copies of Official Seismic Hazard Zone Maps, released by CGS, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available for purchase from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at CGS offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

The Act directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. The Act also directed CGS to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Zone Report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historical ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Sleepy Valley 7.5-Minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Sleepy Valley 7.5-Minute Quadrangle, Los Angeles County, California

By
Ralph C. Loyd

California Department of Conservation
California Geological Survey

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing liquefaction hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee under the auspices of the Southern California Earthquake Center (SCEC).

The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of liquefaction analysis, evaluation, and mitigation techniques (SCEC, 1999). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Sleepy Valley 7.5-Minute Quadrangle. Section 2 (addressing earthquake-induced landslides) and Section 3 (addressing potential ground shaking), complete the report, which is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazards zone mapping in California is on CGS's Internet web page: http://www.consrv.ca.gov/CGS/index.htm

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern, most notably in some densely populated valley regions and alluviated floodplains. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in, including areas in the Sleepy Valley Quadrangle.

METHODS SUMMARY

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Existing geologic maps were used to provide an accurate representation of the spatial distribution of Quaternary deposits in the study area. Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill

- Ground-water maps constructed to show the historically highest known ground-water levels

- Geotechnical data analyzed to evaluate liquefaction potential of deposits

- Information on potential ground shaking intensity based on CGS probabilistic shaking maps

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the SMGB (DOC, 2000).

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the Sleepy Valley Quadrangle consist mainly of alluviated valleys. CGS's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Sleepy Valley Quadrangle covers about 62 square miles in northern Los Angeles County. The east-trending crest of the Sierra Pelona crosses the center of the quadrangle. Bouquet Canyon, part of Bouquet Reservoir and Leona Valley are on the north side of the mountain crest. Mint Canyon and Sierra Pelona Valley are on the south. The center of the area is 11 miles west of Palmdale and 35 miles northwest of the Los Angeles Civic Center. The northwest-trending San Andreas Rift Zone lies within Leona Valley in the northeastern corner of the quadrangle. The highest point (5,187 feet) in the quadrangle is

Mount McDill on the crest of the Sierra Pelona. The lowest point, below 2,160 feet, is in Mint Canyon in the southwestern corner. Numerous canyons dissect the mountains. Creeks on the southern side of the Sierra Pelona flow into the Soledad Basin and on the northern side creeks flow toward the Antelope Valley.

The Angeles National Forest boundary cuts in stair-step fashion from north to south across the center of the quadrangle. National forest land covers about 50 percent of the quadrangle. Numerous parcels of private land are scattered within the forest, especially along Bouquet Canyon. The communities of Leona Valley, Sleepy Valley, and Agua Dulce and all of the private land in the quadrangle are unincorporated Los Angeles County land. Land use includes ranching, rural residential areas, and recreation. Approximately 69 percent (43 square miles) of the quadrangle was evaluated for zoning.

Access to the region is via the Sierra Highway on the south, Bouquet Canyon Road in the center, and Elizabeth Lake – Pine Canyon Road on the north.

GEOLOGY

Bedrock and Surficial Geology

Geologic units that are generally susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. The evaluation of the Sleepy Valley Quadrangle was primarily based on geologic maps by Barrows and others (1985) and Dibblee (1997). The Southern California Areal Mapping Project [SCAMP] and CGS digitized the maps, respectively. Also taken into consideration was a map by Ponti and others (1981).

Plate 1.1 shows the generalized Quaternary geology of the Sleepy Valley Quadrangle using, for reasons of scale, the more generalized map of Dibblee (1997). As shown on Plate 1.1, Quaternary alluvial deposits cover less than 10 percent of the quadrangle. These Pleistocene through Holocene surficial deposits are summarized in Table 1.1 and discussed below. The remainder of the quadrangle consists of pre-Quaternary sedimentary, granitic, and metamorphic rocks. The bedrock units are discussed in the earthquake-induced landslide portion (Section 2) of this report.

In short, Barrows and others (1985) divided Quaternary deposits mainly on the basis of relative age (for example, Qoa, Qal) or environment of deposition, for example, stream channel (Qsc), alluvial fan (Qf), and lake deposits (Ql). In the Sleepy Valley Quadrangle Dibblee (1997) divides Quaternary deposits on the basis of age, older (Qoa) and younger (Qa) deposits, and type such as stream deposits (Qg) or valley alluvium (Qa). Quaternary units in the quadrangle are described below.

North of the San Andreas Fault, Barrows and others (1985) show remnants of older fan deposits (Qof) scattered on the southern slopes of Portal Ridge. Younger alluvial units include fan deposits (Qf), terrace deposits (Qt), lake deposits (Ql), ponded alluvium (Qpa), slope wash deposits (Qsw), and alluvium (Qal). Small areas of artificial fill associated with road construction are also present.

South of the San Andreas Fault, Dibblee (1997) mapped large areas of older dissected surficial sediments that include alluvial gravel and sand of mostly granitic debris (Qoa) and alluvial gravel and sand of mostly Pelona Schist detritus (Qos). All younger alluvial units were mapped as surficial sediments (Qa).

On the slopes south of Leona Valley east of the mouth of Bouquet Canyon Barrows and others (1985) mapped a dissected apron of older alluvial debris comprised of Pelona Schist clasts (Qopl). Younger units include fan deposits (Qf) and alluvium (Qal; Qa of Dibblee, 1997). South of the Sierra Pelona Dibblee (1997) mapped large areas of older dissected surficial sediments that include alluvial gravel and sand of mostly granitic debris (Qoa) and alluvial gravel and sand of mostly Pelona Schist detritus (Qos). Dibblee (1997) mapped all younger alluvial units as surficial sediments (Qa).

Map Unit		Environment of Deposition	Age
Barrows and others (1985)	**Dibblee (1997)**		
Qal, Qf, Ql, Qpa, Qsw, Qsc, Qt	Qa, Qg	alluvial fan, wash, pond, terrace colluvial apron	latest Pleistocene and Holocene
Qoa, Qof, Qopo, Qopl	Qoa, Qos	alluvial fan, wash, colluvial apron	late Pleistocene
Qhp	Qoa	Alluvial fan	late Pleistocene

Table 1.1. Map Units Used in the Sleepy Valley Quadrangle

Structural Geology

Several regional structural features occur within the Sleepy Valley Quadrangle. Within the San Andreas Fault Zone strands considered to have been active during Holocene time are included in the Official Earthquake Fault Zone prepared by CDMG (1979). The San Andreas Fault is a major potential seismic source (Petersen and others, 1996; also see Section 3 of this report). In the northeastern corner the San Andreas Fault Zone separates geologic terranes with dissimilar rock assemblages. Topographically, the San Andreas Fault lies within a linear, trough-like valley called the San Andreas Rift Zone. On the north Portal Ridge borders the zone. Within the fault zone is the center trough ridge, which is composed mostly of Anaverde Formation sandstone. South of the fault Leona Valley is bordered on the west by mountains that consist of dioritic gneiss. This block of igneous and metaigneous rocks is bordered on the south in Bouquet Canyon by the San Francisquito Fault (Dibblee, 1997). South of the San Francisquito Fault the central third of the quadrangle consists of the Sierra Pelona, which is a westward-plunging antiform comprised entirely of Pelona Schist. The mylonitic rocks at the contact between the Pelona Schist and the granitic rocks to the south have been interpreted as being associated with a segment of the south-dipping Vincent Thrust Fault (Ehlig, 1968). The thrust has been described as the most important structural feature in the basement rocks of the San Gabriel Mountains (Ehlig, 1981). The Precambrian basement rocks, such as the ferruginous syenite and augen gneiss that are exposed within the southern part of the Sleepy Valley Quadrangle are western extensions of the San Gabriel Mountains basement terrane. The overlying Vasquez Formation fluvial sedimentary rocks are manifestations of the eastern part of the Soledad Basin, which widens and deepens to the west of the quadrangle.

ENGINEERING GEOLOGY

As stated above, soils that are generally susceptible to liquefaction are mainly late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. Deposits that contain saturated, loose sandy and silty soils are most susceptible to liquefaction. Lithologic descriptions and soil test results reported in geotechnical borehole logs provide valuable information regarding subsurface geology, ground-water levels, and the engineering characteristics of sedimentary deposits.

Of particular value in liquefaction evaluations are logs that report the results of downhole standard penetration tests. Standard Penetration Tests (SPTs) provide a uniform measure of the penetration resistance of geologic deposits and are commonly used as an index of soil density. This in-field test consists of counting the number of blows required to drive a split-spoon sampler (1.375-inch inside diameter) one foot into the soil at the bottom of a borehole at chosen intervals while drilling. The driving force is provided by dropping a 140-pound hammer weight 30 inches. The SPT method is formally defined and specified by the American Society for Testing and Materials in test method D1586 (ASTM, 1999). Recorded blow counts for non-SPT geotechnical sampling where the sampler diameter, hammer weight or drop distance differ from those specified for an SPT (ASTM D1586), are converted to SPT-equivalent blow counts. The actual and converted SPT blow counts are normalized to a common-reference, effective-overburden pressure of one atmosphere (approximately one ton per square foot) and a hammer efficiency of 60 percent using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as $(N_1)_{60}$.

The Seed-Idriss Simplified Procedure for liquefaction evaluation was developed primarily for clean sand and silty sand. As described above, results depend greatly on accurate evaluation of in-situ soil density as measured by the number of soil penetration blow counts using an SPT sampler. However, many of the Holocene alluvial deposits in the study area contain a significant amount of gravel. In the past, gravelly soils were considered not to be susceptible to liquefaction because the high permeability of these soils presumably would allow the dissipation of pore pressures before liquefaction could occur. However, liquefaction in gravelly soils has been observed during earthquakes, and recent laboratory studies have shown that gravelly soils are susceptible to liquefaction (Ishihara, 1985; Harder and Seed, 1986; Budiman and Mohammadi, 1995; Evans and Zhou, 1995; and Sy and others, 1995). SPT-derived density measurements in gravelly soils are unreliable and generally too high. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To identify potentially liquefiable units where the N values appear to have been affected by gravel content, correlations were made with boreholes in the same unit where the N values do not appear to have been affected by gravel content.

During the initial stages of this investigation, CGS obtained logs of geotechnical boreholes that had been drilled in various localities within Antelope Valley. Staff collected the logs from the files of the cities of Lancaster and Palmdale, California Department of Transportation, Los Angeles County Public Works Department, and Earth Systems, Inc. Fifteen of the logs collected are from boreholes drilled and trenches excavated within the Sleepy Valley Quadrangle. These sites were digitally located and associated log data entered into the CGS geotechnical GIS database to enable computer-assisted analysis and evaluation.

Examination of borehole logs indicates that Leona Valley includes sedimentary deposits composed of loose to moderately dense sandy and silty sediments. The lithologic descriptions provided in geotechnical borehole and trench logs were augmented by examination of lithologic descriptions included in the logs of water wells drilled in the study area.

Geologic Map Unit*	**Material Type**	**Consistency**	**Age**	**Liquefaction Susceptibility****
stream channel, wash (Qsc; Qg)	medium to coarse sand and gravel	very loose	latest Holocene	high
(Qsd)	sand	very loose	Holocene & late Pleistocene	high
wash (Qsc; Qa)	sand, gravel, & silt	Loose	Holocene & late Pleistocene	high
alluvium, alluvial fan, wash (Qa: Qf, Ql, Qpa, Qt)	sand, gravel, & silt	loose to moderately dense	Holocene & late Pleistocene	high to moderate
alluvium, alluvial fan (Qoa, Qof, Qopl, Qopo)	gravel, sand, silt, clay	Dense	Pleistocene	low
alluvium, alluvial fan (Qhp: Qoa)	gravel, sand, silt, clay	Dense	Pleistocene	low

* see Table 1.1 for map unit correlation between Barrows and others (1985) and Dibblee (1997).
**when saturated

Table 1.2. Quaternary Map Units Used in the Sleepy Valley 7.5-Minute Quadrangle and Their Geotechnical Characteristics and General Liquefaction Susceptibility

GROUND WATER

An essential element in evaluating liquefaction susceptibility is the determination of the depths at which soils are saturated by ground water. Saturated conditions reduce the effective normal stress acting on loose, near-surface sandy deposits, thereby increasing the likelihood of liquefaction (Youd, 1973). For zoning purposes, "near surface deposits" include those sediment layers between 0 and 40 feet deep, the interval being derived from item 4a of the SMGB criteria for delineating seismic hazard zones in California (DOC, 2000; see Criteria for Zoning section of this report). Liquefaction evaluations, therefore, concentrate on areas where investigations indicate that young Quaternary sediments might be saturated within 40 feet of the ground surface. Unfortunately, unpredictable and dramatic fluctuations in ground water caused by natural processes and human activities make it impossible to anticipate water levels that might exist at the time of future earthquakes. For that reason, CGS uses historically high ground-water levels for evaluating and zoning liquefaction potential. This approach assumes that even in areas where levels are presently significantly lower, ground water could return to historically high levels in the future. This, in fact, has occurred in basins where water-importing urbanized areas have replaced vast farm and orchard lands that were characterized by substantial ground-water withdrawal (for example, Simi Valley, Ventura County) as well as in basins where large-scale ground-water recharge programs are employed.

Plate 1.2 depicts historically shallowest depths to ground water in alluviated areas of the quadrangle. In Leona Valley and Pelona Valley ground-water levels have been measured at less than 10 feet. In narrow (restricted) canyons ground water depth is assumed to be less than 10 feet during wet periods. Sources of ground-water data used in this report include California Department of Water Resources (2003) and borehole logs collected in the course of this study (see Engineering Geology section).

PART II

LIQUEFACTION POTENTIAL

Liquefaction may occur in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction. Liquefaction opportunity is a function of the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. CGS's method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the SMGB (DOC, 2000).

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment's geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

CGS's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps

LIQUEFACTION OPPORTUNITY

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10 percent probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in CGS's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Sleepy Valley Quadrangle, PGAs ranging from 0.51 to 0.75g, resulting from a predominant earthquake of magnitude 7.8, were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10 percent in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen, 1996). See the ground motion portion (Section 3) of this report for further details.

Quantitative Liquefaction Analysis

CGS performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997; Youd and others, 2001). Using the Seed-Idriss Simplified Procedure one can calculate soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The Seed-Idriss Simplified Procedure requires normalizing earthquake loading relative to a M7.5 event for the liquefaction analysis. To accomplish this, CGS's analysis uses the Idriss magnitude-scaling factor (MSF) (Youd and Idriss, 1997). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where: FS = (CRR / CSR) * MSF. FS, therefore, is a quantitative measure of liquefaction potential. CGS uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures.

The CGS liquefaction analysis program calculates an FS for each geotechnical sample where blow counts were collected. Typically, multiple samples are collected for each borehole. The program then independently calculates an FS for each non-clay layer that includes at least one penetration test using the minimum $(N_1)_{60}$ value for that layer. The minimum FS value of the layers penetrated by the borehole is used to determine the liquefaction potential for each borehole location. The reliability of FS values varies according to the quality of the geotechnical data. FS, as well as other considerations such as slope, presence of free faces, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation.

Nearly half of the 15 geotechnical borehole logs reviewed in this study (Plate 1.2) include blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2½-inch inside-diameter ring samplers, are generally translated to SPT-equivalent values if reasonable factors can be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (e.g. soil density, moisture content, sieve analysis, etc.) required for an ideal Seed-Idriss Simplified Procedure. For boreholes having acceptable penetration tests, liquefaction analysis is performed using recorded density, moisture, and sieve test values or using averaged test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the SMGB (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes
2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated
3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable
4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the Sleepy Valley Quadrangle is summarized below.

Areas of Past Liquefaction

Documentation of historical liquefaction or paleoseismic liquefaction in the Sleepy Valley Quadrangle was not found during this study.

Artificial Fills

Artificial fill large enough to show at the scale of mapping is limited road and home construction. Since this is considered to be properly engineered, zoning for liquefaction in such areas depends on soil conditions in underlying strata. Non-engineered fills are commonly loose and uncompacted, and the material varies in size and type.

Areas with Sufficient Existing Geotechnical Data

Geologic mapping, geotechnical borehole and water-well data, and liquefaction analysis using the Seed-Idriss Simplified Procedure provided a generally sound basis for evaluating liquefaction potential in the Leona Valley area of the Sleepy Valley Quadrangle. The log descriptions and liquefaction analysis indicate that near surface young Quaternary sedimentary deposits in Leona Valley are dominated by loose, sandy material that could liquefy where saturated under historically shallowest ground-water conditions presented on Plate 1.2. Consequently, much of Leona Valley is designated as zones of required investigation on the Seismic Hazard Zone Map of the Sleepy Valley Quadrangle.

Areas with Insufficient Existing Geotechnical Data

Identified as potentially liquefiable through application of SMGB Seismic Hazard Zoning Criterion Item 4 is the young Quaternary alluvium contained in the drainage areas of Pelona Valley and various canyon areas throughout the evaluated part of the quadrangle. These areas are designated zones of required investigation on the Seismic Hazard Zone Map of the Sleepy Valley Quadrangle.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Sleepy Valley 7.5-Minute Quadrangle, Los Angeles County, California

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PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps prepared by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing landslide hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee in 1998 under the auspices of the Southern California Earthquake Center (SCEC). The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of landslide analysis, evaluation, and mitigation techniques (SCEC, 2002). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Sleepy Valley 7.5-Minute Quadrangle. Section 1 (addressing liquefaction) and Section 3 (addressing earthquake shaking) complete the report, which is one of a series that summarizes the preparation of seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

BACKGROUND

Landslides triggered by earthquakes historically have been a significant cause of earthquake damage. In California, large earthquakes such as the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes triggered landslides that were responsible for destroying or damaging numerous structures, blocking major transportation corridors, and damaging life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, areas underlain by loose, weak soils, and areas on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, including numerous hillside areas that have already been developed or are likely to be developed in the future. The opportunity for strong earthquake ground shaking is high in many parts of California because of the presence of numerous active faults. The combination of these factors constitutes a significant seismic hazard throughout much of California, including the hillside areas of the Sleepy Valley Quadrangle.

METHODS SUMMARY

The mapping of earthquake-induced landslide hazard zones presented in this report is based on the best available terrain, geologic, geotechnical, and seismological data. If unavailable or significantly outdated, new forms of these data were compiled or generated specifically for this project. The following were collected or generated for this evaluation:

- Digital terrain data were used to provide an up-to-date representation of slope gradient and slope aspect in the study area.

- Geologic mapping was used to provide an accurate representation of the spatial distribution of geologic materials in the study area. In addition, a map of existing landslides, whether triggered by earthquakes or not, was prepared.

- Geotechnical laboratory test data were collected and statistically analyzed to quantitatively characterize the strength properties and dynamic slope stability of geologic materials in the study area.

- Seismological data in the form of CGS probabilistic shaking maps and catalogs of strong-motion records were used to characterize future earthquake shaking within the mapped area.

The data collected for this evaluation were processed into a series of GIS layers using commercially available software. A slope stability analysis was performed using the Newmark method of analysis (Newmark, 1965), resulting in a map of landslide hazard potential. The earthquake-induced landslide hazard zone was derived from the landslide hazard potential map according to criteria developed in a CGS pilot study (McCrink and Real, 1996; McCrink, 2001) and adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered from a variety of outside sources. Although the selection of data used in this evaluation was rigorous, the quality of the data is variable. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Sleepy Valley Quadrangle, for more information on the delineation of liquefaction zones.

The remainder of this report describes in more detail the mapping data and processes used to prepare the earthquake-induced landslide zone map for the Sleepy Valley Quadrangle. The information is presented in two parts. Part I covers physiographic, geologic and engineering geologic conditions in the study area. Part II covers the preparation of landslide hazard potential and landslide zone maps.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Sleepy Valley Quadrangle covers about 62 square miles in northern Los Angeles County. The east-trending crest of the Sierra Pelona crosses the center of the quadrangle. Bouquet Canyon, part of Bouquet Reservoir and Leona Valley are on the north side of the mountain crest. Mint Canyon and Sierra Pelona Valley are on the south. The center of the area is 11 miles west of Palmdale and 35 miles northwest of the Los Angeles Civic Center. The northwest-trending San Andreas Rift Zone lies within Leona Valley in the northeastern corner of the quadrangle. The highest point (5,187 feet) in the quadrangle is Mount McDill on the crest of the Sierra Pelona. The lowest point, below 2,160 feet, is in Mint Canyon in the southwestern corner. Numerous canyons dissect the mountains. Creeks on the southern side of the Sierra Pelona flow into the Soledad Basin and on the northern side, creeks flow toward the Antelope Valley.

The Angeles National Forest boundary cuts in stair-step fashion from north to south across the center of the quadrangle. National forest land covers about 50 percent of the quadrangle. Numerous parcels of private land are scattered within the forest, especially along Bouquet Canyon. The communities of Leona Valley, Sleepy Valley, and Agua Dulce and all of the private land in the quadrangle are unincorporated Los Angeles County land. Land use includes ranching, rural residential areas, and recreation. Approximately 69 percent (43 square miles) of the quadrangle was evaluated for zoning.

Access to the region is via the Sierra Highway on the south, Bouquet Canyon Road in the center, and Elizabeth Lake – Pine Canyon Road on the north.

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth's surface in the form of a digital topographic map. Within the Sleepy Valley Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, prepared from the 7.5-minute quadrangle topographic contours based on 1956 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

A slope map was made from the DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The DEM was also used to make a slope aspect map. The manner in which the slope and aspect maps were used to prepare the zone map will be described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

The geologic map used as background geology for the Sleepy Valley Quadrangle was prepared from two sources. Detailed geologic maps of the San Andreas Fault Zone, including the segment that crosses the Sleepy Valley Quadrangle, were prepared by Barrows and others (1985, Plate 1D). This map, which only covers the northeastern corner of the quadrangle, was digitized by the Southern California Areal Mapping Project [SCAMP]. A geologic map by Dibblee (1997) was digitized by CGS for the remainder of the quadrangle south of the detailed strip map along the fault zone. During the search for landslides in the field, observations were made of exposures, aspects of weathering and general surface expression of the geologic units.

Because rock assemblages are distinct for areas that are north of and within and south of the San Andreas Fault Zone, these areas are discussed separately.

North of and within the San Andreas Fault Zone

Pre-Tertiary Portal Schist (pos) is the oldest rock unit north of the main trace of the San Andreas Fault. Portal Schist is well exposed on Portal Ridge and consists of quartzo-feldspathic and dark biotite schist, with common marble and quartzite interlayers and abundant vein quartz (Barrows and others, 1985).

The San Andreas Fault Zone consists of two dominant strands where it crosses the Sleepy Valley Quadrangle. These strands, the “north branch” and the “main” or southern trace are separated by a linear ridge along the northeastern margin of Leona Valley (Barrows and others, 1985). Exposed within this “center trough ridge” are several members of the non-marine Pliocene Anaverde Formation. The subunits include the red arkose, buff arkose, clay shale, and breccia members (Barrows and others, 1985). The red arkose member (Tar) is a pink to red, medium-to thick-bedded, locally massive, coarse pebbly arkose. The buff arkose (Tab) is a buff to gray, medium-bedded to massive, medium- to very coarse-grained pebbly arkose with thin silty interbeds near the top. The clay shale member (Tac) is a gray to brown, thin-bedded, sandy, silty, locally very gypsiferous clay shale with interbedded siltstone and sandstone layers. The breccia member (Tabx) is a very distinctive, reddish to dark gray, massive, pervasively sheared sedimentary breccia with angular clasts of hornblende diorite. It occurs only within the San Andreas Fault Zone. Bedding within the Anaverde Formation mostly parallels the bounding faults and has steep to vertical dips.

Remnants of older fan deposits (Qof) are scattered on the southern slopes of Portal Ridge. Younger alluvial units include fan deposits (Qf), terrace deposits (Qt), lake deposits (Ql), ponded alluvium (Qpa), slope wash deposits (Qsw), and alluvium (Qal). Small areas of artificial fill associated with road construction are also present.

South of the San Andreas Fault

The Sleepy Valley Quadrangle lies mostly south of the San Andreas Fault Zone. The eastern end of a large body of pre-Tertiary gneissic diorite and granodiorite is exposed in the mountainous terrain southwest of Leona Valley in the northern third of the quadrangle. These rocks were mapped as a gneiss complex (dgn) of dark gray to black and white igneous, meta-igneous and metasedimentary rocks, migmatite, gneissic diorite, quartz diorite and granodiorite (Barrows and others, 1985). Dgn is typically deeply weathered, commonly sheared and shattered, and rarely yields debris coarser than small pebbles. In the portion of the quadrangle compiled from the geologic map by Dibblee (1997) rocks of the gneissic diorite complex were mapped as quartz diorite (qd) that contains local concentrations of biotitic gray gneiss (gn) and rare diorite (di), and granite (gr) dikes. The southern boundary of the diorite gneiss complex is the San Francisquito Fault, which crosses the entire quadrangle mostly within Bouquet Canyon.

South of Bouquet Canyon more than half of the quadrangle consists of pre-Tertiary Pelona Schist (pls [Barrows and others, 1985]; ps [Dibblee, 1997]). Pelona Schist is predominantly silver to dark-gray, fine- to medium-grained, well-foliated to massive, quartz-muscovite schist with interlayers of quartzo-feldspathic and greenish chlorite-epidote schist and white quartz veins. Dibblee (1997) mapped a few very small occurrences of schist with banded marble (psl) and schist with quartzite (psq) within the Sierra Pelona. Dibblee (1997) also mapped mylonite zones (my) along the southern margin of the Sierra Pelona.

Precambrian basement rocks such as gray banded gneiss (gnb), dark gray augen gneiss (agn) and distinctive red-weathering ferruginous syenite (sy) are exposed south of the Sierra Pelona. These ancient rocks have been intruded by pre-Tertiary diorite (di), hornblende diorite (hd) and a variety of light-colored granitic rocks (gr) as shown on the map be Dibblee (1997).

Also within the southwestern corner of the quadrangle Dibblee (1997) mapped Oligocene nonmarine, coarse red conglomerate (Tvcg) and red conglomerate and sandstone (Tvcs) of the Vasquez Formation. No Vasquez Formation volcanic rocks are mapped in the Sleepy Valley Quadrangle. The only other pre-Quaternary rocks mapped (Barrows and others, 1985) in the quadrangle are a few exposures in Leona Valley of rocks of Ritter Formation (TQr), which is a light gray to white, moderately well-indurated to poorly indurated, thin- to medium-bedded fluvial sandstone with thin micaceous shale layers. Clasts in the Ritter Formation appear to have been derived from the diorite and gneiss complex west of the Sierra Pelona (Barrows and others, 1985).

Dibblee (1997) mapped large areas of older dissected surficial sediments that include alluvial gravel and sand of mostly granitic debris (Qoa) and alluvial gravel and sand of mostly Pelona Schist detritus (Qos). All younger alluvial units were mapped as surficial sediments (Qa).

On the slopes south of Leona Valley east of the mouth of Bouquet Canyon is a dissected apron (Barrows and others, 1985) of older alluvial debris comprised of Pelona Schist clasts (Qopl). Dibblee (1997) mapped these deposits as Pelona Schist debris (Qos). Younger units include fan deposits (Qf) and alluvium (Qal; Qa of Dibblee, 1997). South of the Sierra Pelona Dibblee (1997) mapped large areas of older dissected surficial sediments that include alluvial gravel and sand of mostly granitic debris (Qoa) and alluvial gravel and sand of mostly Pelona Schist detritus (Qos). Dibblee (1997) mapped all younger alluvial units as surficial sediments (Qa).

Structural Geology

Several regional structural features occur within the Sleepy Valley Quadrangle. In the northeastern corner the San Andreas Fault Zone separates geologic terranes with dissimilar rock assemblages. Topographically, the San Andreas Fault lies within a linear, trough-like valley called the San Andreas Rift Zone. On the north Portal Ridge borders the zone. Within the fault zone is the center trough ridge, which is composed mostly of Anaverde Formation sandstone. South of the fault Leona Valley is bordered on the west by mountains that consist of dioritic gneiss. This block of igneous and metaigneous rocks is bordered on the south in Bouquet Canyon by the San Francisquito Fault (Dibblee, 1997). South of the San Francisquito Fault the central third of the quadrangle consists of the Sierra Pelona, which is a westward-plunging antiform comprised entirely of Pelona Schist. The mylonitic rocks at the contact between the Pelona Schist and the granitic rocks to the south have been interpreted as being associated with a segment of the south-dipping Vincent Thrust Fault (Ehlig, 1968). The thrust has been described as the most important structural feature in the basement rocks of the San Gabriel Mountains (Ehlig, 1981). The Precambrian basement rocks, such as the ferruginous syenite and augen gneiss that are exposed within the southern part of the Sleepy Valley Quadrangle are western extensions of the San Gabriel Mountains basement terrane. The overlying Vasquez Formation fluvial sedimentary rocks are manifestations of the eastern part of the Soledad Basin, which widens and deepens to the west of the quadrangle.

Landslide Inventory

As a part of the geologic data compilation, an inventory of existing landslides in the Sleepy Valley Quadrangle was prepared by field reconnaissance, analysis of stereo-paired aerial photographs and a review of previously published and unpublished landslide mapping. The geology and landslide maps and reports that were reviewed during preparation of the landslide inventory include Jahns and Muehlberger (1954), Dibblee (1961; 1997), and Buena Engineers, Inc. (1989). Landslides were mapped at a scale of 1:24,000. For each landslide included on the map a number of characteristics (attributes) were compiled. These characteristics include the confidence of interpretation (definite, probable and questionable) and other properties, such as activity, thickness, and associated geologic unit(s). Landslides rated as definite and probable were carried into the landslide zoning as described later in this report. Landslides rated as questionable were not carried into the slope stability analysis due to the uncertainty of their existence. The completed landslide map was digitized and the attributes were compiled in a database. A version of this landslide inventory is included with Plate 2.1.

Landslides are most abundant along the steep north- and south-facing slopes of the Sierra Pelona in the central part of the Sleepy Valley Quadrangle where metamorphic rocks of the Pelona Schist have been complexly folded and faulted during several periods of tectonic deformation. Regional foliation attitudes indicate that the schist forms dipslopes on both sides of the Sierra Pelona antiform, increasing the potential for slope instability.

Locally, the Pelona Schist is characterized by tight folding, internal shearing, jointing, and fracturing, making it difficult to distinguish between in-situ tectonically deformed and weathered bedrock and disturbed bedrock caused by mass movement. Landslide interpretation is further complicated by the presence within the schist of relatively resistant lenses of quartz and marble, which have an influence on differential erosion that results in hummocky topography. In addition, most of the older landslides in the area have been extensively modified by erosion. The boundaries of the large, older landslides mapped as part of this study were determined primarily from air-photo interpretation.

Landslides in the area range from small surficial failures along roadcuts and streamcuts to very large translational and rotational landslides. Most of the larger landslides are ancient composite failures exhibiting different types of movement in different parts of the landslide. In many cases, the lower portions of these slide masses have yielded debris flows.

Because it is not within the scope of the Act to review and monitor grading practices to ensure past slope failures have been properly mitigated, all documented slope failures, whether or not surface expression currently exists, are included in the landslide inventory.

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strength. Generally, the primary source for shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear-strength data for the units identified on the Sleepy Valley Quadrangle geologic map were obtained from County of Los Angeles- Department of Public Works (see Appendix A). The locations of rock and soil samples taken for shear testing within the Sleepy Valley Quadrangle are shown on Plate 2.1. Shear tests from the adjoining Ritter Range, Aqua Dulce, Lake Hughes, and Del Sur quadrangles were used to augment data for several geologic formations for which little or no shear test information was available within the Sleepy Valley Quadrangle.

Shear strength data gathered from the above sources were compiled for each geologic map unit. Geologic units were grouped on the basis of average angle of internal friction (average phi) and lithologic character. Average (mean or median) phi values for each geologic map unit and corresponding strength group are summarized in Table 2.1. For most of the geologic strength groups (Table 2.2) in the map area, a single shear strength value was assigned and used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Table 2.1 and Table 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis.

Existing Landslides

As discussed later in this report, the criteria for landslide zone mapping state that all existing landslides that are mapped as definite or probable are automatically included in the landslide zone of required investigation. Therefore, an evaluation of shear strength parameters for existing landslides is not necessary for the preparation of the zone map. However, in the interest of completeness for the material strength map, to provide relevant material strength information to project plan reviewers, and to allow for future revisions of our zone mapping procedures, we have collected and compiled shear strength data considered representative of existing landslides within the quadrangle.

The strength characteristics of existing landslides (Qls) must be based on tests of the materials along the landslide slip surface. Ideally, shear tests of slip surfaces formed in each mapped geologic unit would be used. However, this amount of information is rarely available, and for the preparation of the earthquake-induced landslide zone map it has been assumed that all landslides within the quadrangle have the same slip surface strength parameters. We collect and use primarily “residual” strength parameters from laboratory tests of slip surface materials tested in direct shear or ring shear test equipment. Back-calculated strength parameters, if the calculations appear to have been performed appropriately, have also been used. For the Sleepy Valley Quadrangle, no shear tests of landslide slip surface materials were available. A phi value of 16 degrees was derived from shear tests collected in the nearby Mint Canyon Quadrangle and was judged to be representative of the relatively few landslides in the study area.

SLEEPY VALLEY QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name	Number Tests	Mean/Median Phi (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	sy qd* di	6 3 3	39/39 34/35 42/41	37/38	694/500	my	38
GROUP 2	Tvcg psp ps gr	1 3 2 7	38/38 30/31 35/35 34/35	34/35	473/300	Tvab, Tvcg, Tvcgl, Tvcs, Tvgb, actinolite***, agn, gnb, hd, pls, pos, psl, pso, psq, q, talc***	34
GROUP 3	Tas Qa** af	1 33 1	38/38 30/30 20/20	29/31	260/216	Qal, Qf, Qhp, Ql, Qoa, Qof, Qopl, Qopo, Qos, Qpa, Qsc, Qsw, Qt, TQal, TQr, Tab, Tabx, Tac, Tar, al	29
GROUP 4						Qls	16

qd* = Includes dgn, gn

Qa** = Includes Qal, Qf, Qhp, Ql, Qoa, Qof, Qopl, Qos, Qpa, Qsc, Qsw, Qt, and Tqal
*** = actinolite and talc outcrops are considered minor enough to be incorporated within their host-rock formations.
Formation abbreviations from Dibblee (1997), and Barrows and others (1985)

Table 2.1. Summary of the Shear Strength Statistics for the Sleepy Valley Quadrangle.

SHEAR STRENGTH GROUPS FOR THE SLEEPY VALLEY 7.5-MINUTE QUADRANGLE

GROUP 1	GROUP 2	GROUP 3	GROUP 4
sy, qd, di, my	Tvcg, psp, ps, gr, Tvab, Tvcg, Tvcgl, Tvcs, Tvgb, actinolite, agn, gnb, hd, pls, pos, psl, pso, psq, q, talc	Tas, Qa, af, Qal, Qf, Qhp, Ql, Qoa, Qof, Qopl, Qopo, Qos, Qpa, Qsc, Qsw, Qt, TQal, TQr, Tab, Tabx, Tac, Tar, al	Qls

Table 2.2. Summary of Shear Strength Groups for the Sleepy Valley Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity." For the Sleepy Valley Quadrangle, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by CGS for a 10 percent probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	7.8
Modal Distance:	2.6 to 15.5 km
PGA:	0.5 to 0.9g

The strong-motion record selected for the slope stability analysis in the Sleepy Valley Quadrangle was the Southern California Edison Lucerne record from the 1992 magnitude 7.3 Landers, California, earthquake was used because it was the closest fit to the above criteria. This record had a source to recording site distance of 1.1 km and a peak ground acceleration (PGA) of 0.80g. Although the distance and PGA from the Lucerne record do not fall within the range of the probabilistic parameters, this record was considered to be sufficiently conservative to be used in the stability analyses. The selected strong-motion record was not scaled or otherwise modified prior to its use in the analysis.

Displacement Calculation

The design strong-motion record was used to develop a relationship between landslide displacement and yield acceleration (a_y), defined as the earthquake horizontal ground acceleration above which landslide displacements take place. This relationship was prepared by integrating the design strong-motion record twice for a given acceleration value to find the corresponding displacement, and the process was repeated for a range of acceleration values (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for the design strong-motion record. This curve provides the required link between anticipated earthquake shaking and estimates of displacement for different combinations of geologic materials and slope gradient, as described in the Slope Stability Analysis section below.

The amount of displacement predicted by the Newmark analysis provides an indication of the relative amount of damage that could be caused by earthquake-induced landsliding. Displacements of 30, 15 and 5 cm were used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and a CGS pilot study for earthquake-induced landslides (McCrink and Real, 1996; McCrink, 2001). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.24, 0.18 and 0.14g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant in the Sleepy Valley Quadrangle.

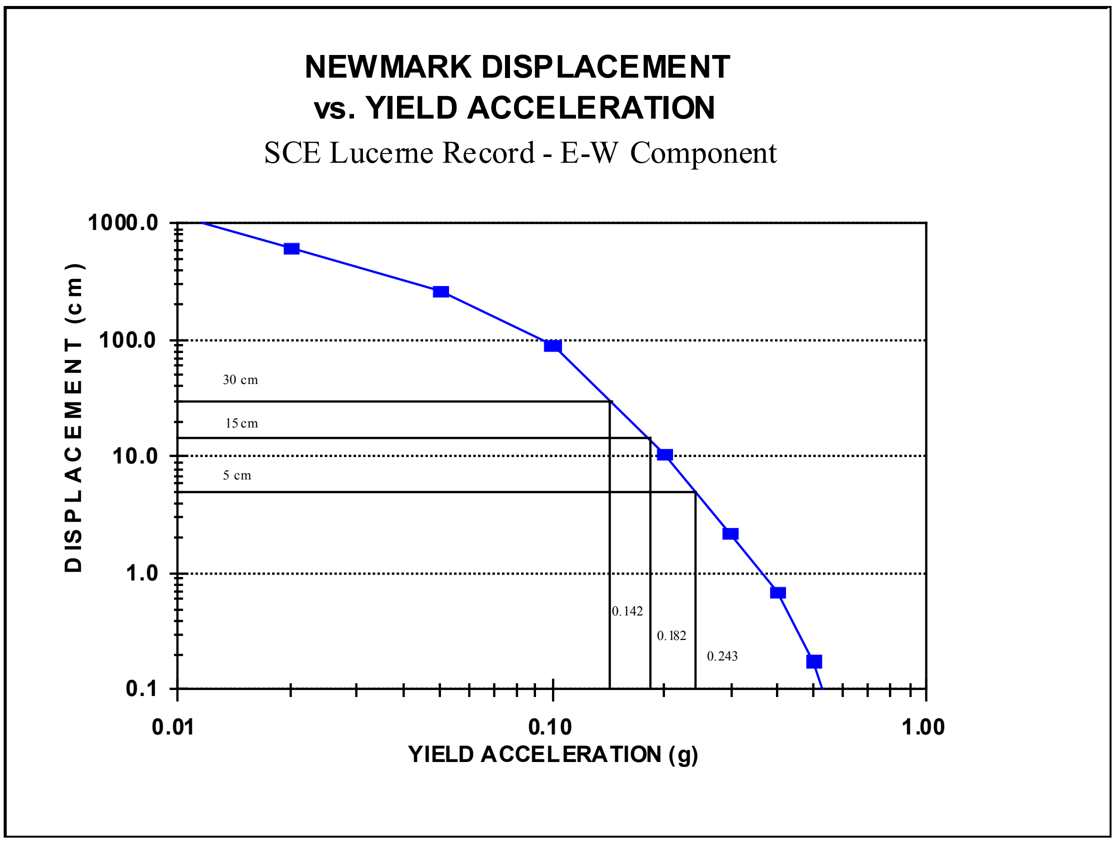

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the Lucerne Record.

Slope Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where **FS** is the Factor of Safety, **g** is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield accelerations resulting from Newmark's equations represent the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. Based on the relationship between yield acceleration and Newmark displacement shown in Figure 2.1, hazard potentials were assigned as follows:

1. If the calculated yield acceleration was less than 0.14g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned.

2. If the calculated yield acceleration fell between 0.18g and 0.14g, Newmark displacement between 15 cm and 30 cm is indicated, and a MODERATE hazard potential was assigned.

3. If the calculated yield acceleration fell between 0.24g and 0.18g, Newmark displacement between 5 cm and 15 cm is indicated, and a LOW hazard potential was assigned.

4. If the calculated yield acceleration was greater than 0.24g, Newmark displacement of less than 5 cm is indicated, and a VERY LOW potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

SLEEPY VALLEY QUADRANGLE HAZARD POTENTIAL MATRIX

Geologic Material Strength Group (Average Phi)	HAZARD POTENTIAL (Percent Slope)			
	Very Low	Low	Moderate	High
1 (38)	0 to 50 %	50 to 57 %	57 to 62 %	>62 %
2 (34)	0 to 41 %	41 to 47 %	47 to 52 %	>52 %
3 (29)	0 to 29 %	29 to 35 %	35 to 39 %	>39 %
4 (16)	0 to 4 %	4 to 9 %	9 to 13 %	>13 %

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Sleepy Valley Quadrangle. Values in the table show the range of slope gradient (expressed as percent slope) corresponding to calculated Newmark displacement ranges from the design earthquake for each material strength group.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (DOC, 2000). Under these criteria, earthquake-induced landslide hazard zones are defined as areas that meet one or both of the following conditions:

1. Areas that have been identified as having experienced landslide movement in the past, including all mappable landslide deposits and source areas as well as any landslide that is known to have been triggered by historic earthquake activity.
2. Areas where the geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

These conditions are discussed in further detail in the following sections.

Existing Landslides

Existing landslides typically consist of disrupted soils and rock materials that are generally weaker than adjacent undisturbed rock and soil materials. Previous studies indicate that existing landslides can be reactivated by earthquake movements (Keefer, 1984). Earthquake-triggered movement of existing landslides is most pronounced in steep head scarp areas and at the toe of existing landslide deposits. Although reactivation of deep-seated landslide deposits is less common (Keefer, 1984), a significant number of deep-seated landslide movements have occurred during, or soon after, several recent earthquakes. Based on these observations, **all existing landslides with a definite or probable confidence rating are included within the earthquake-induced landslide hazard zone.**

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by CGS (McCrink and Real, 1996; McCrink, 2001), it has been concluded that earthquake-induced landslide hazard zones should encompass all areas that have a High, Moderate or Low level of hazard potential (see Table 2.3). This would include all areas where the analyses indicate earthquake displacements of 5 cm or greater. Areas with a Very Low hazard potential, indicating less than 5 cm displacement, are excluded from the zone.

As summarized in Table 2.3, all areas characterized by the following geologic strength group and slope gradient conditions are included in the earthquake-induced landslide hazard zone:

1. Geologic Strength Group 4 is included for all slopes steeper than 4 percent. (Note: The only geologic unit included in Geologic Strength Group 4 is Qls (existing landslides). Qls have been included or excluded from the landslide zones on the basis of the criteria described in the previous section)

2. Geologic Strength Group 3 is included for all slopes steeper than 29 percent.

3. Geologic Strength Group 2 is included for all slopes steeper than 41 percent.

4. Geologic Strength Group 1 is included for all slopes greater than 50 percent.

This results in approximately 13 percent of the area mapped within the quadrangle lying within the earthquake-induced landslide hazard zone for the Sleepy Valley Quadrangle. As previously discussed, approximately 69 percent of the entire quadrangle map area was evaluated for zoning.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals and organizations for their assistance in obtaining the data necessary to complete this project: Charles Nestle and Greg Johnson from Los Angeles County Department of Public Works. At CGS, Terilee McGuire and Bob Moscovitz provided GIS support. Barbara Wanish and Diane Vaughn prepared the final landslide hazard zone maps and the graphic displays for this report. Mike Silva provided assistance with map generation. Ben Wright, Sam Altashi and Ian Penny prepared the shear test database for analysis and digitized borehole locations.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Los Angeles County Department of Public Works	**60**
Aqua Dulce Quadrangle	**76**
Ritter Ridge Quadrangle	**127**
Total Number of Shear Tests	**263**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Sleepy Valley 7.5-Minute Quadrangle, Los Angeles County, California

By

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California Geological Survey
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PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (DOC, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2 (addressing liquefaction and earthquake-induced landslide hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology [California Geological Survey], and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10 percent probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

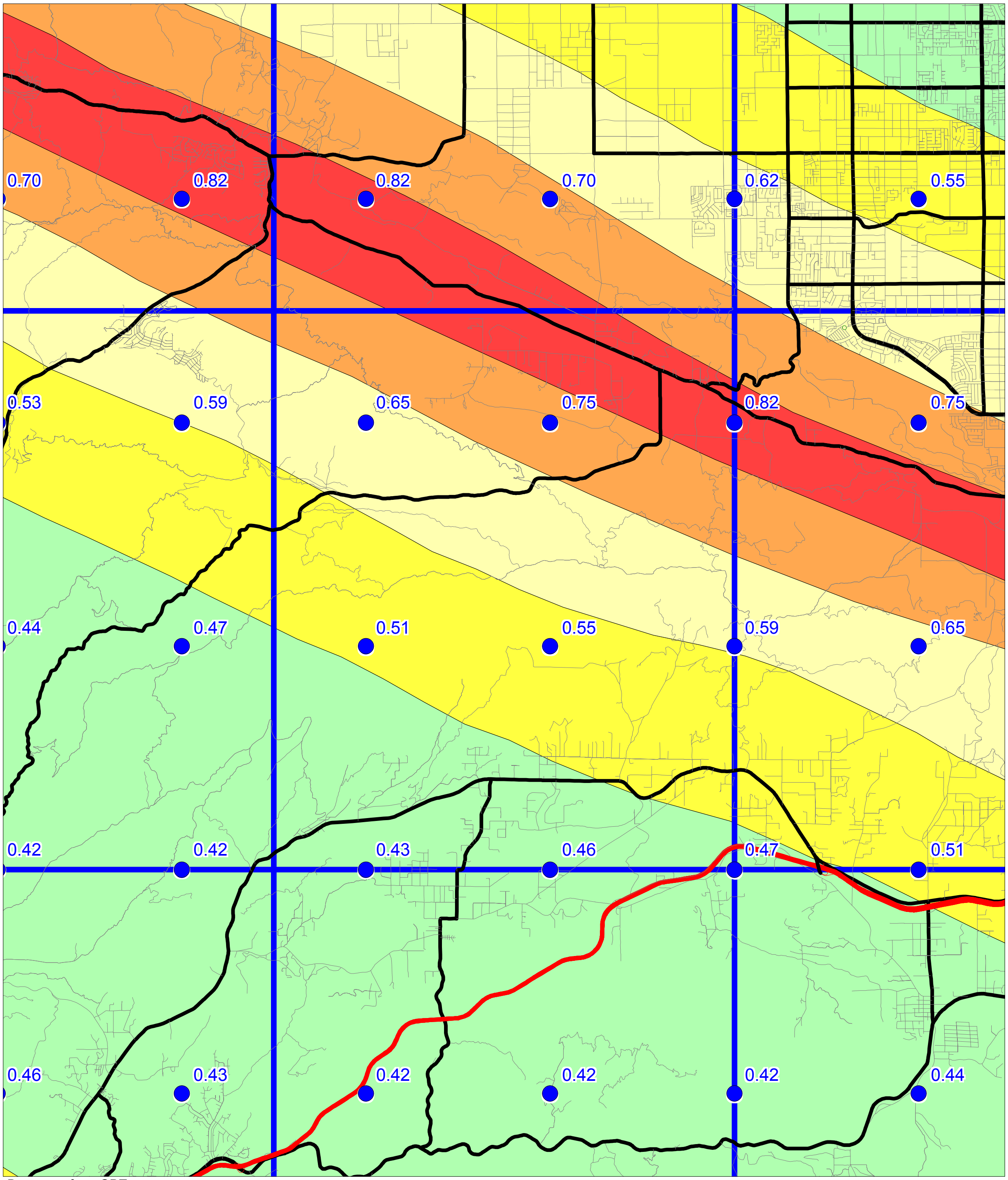
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10 percent probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle

SLEEPY VALLEY 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

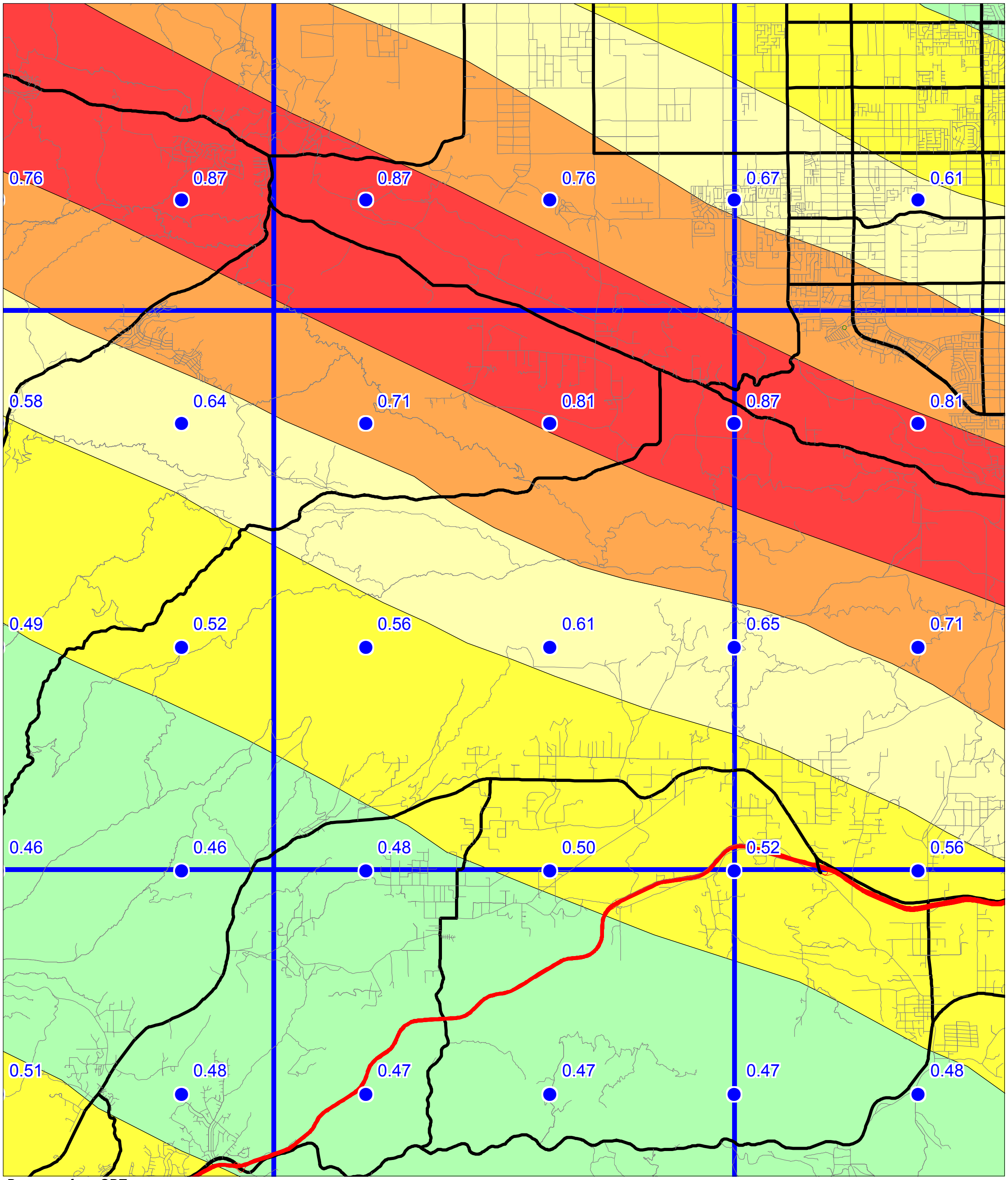
Figure 3.1

SLEEPY VALLEY 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

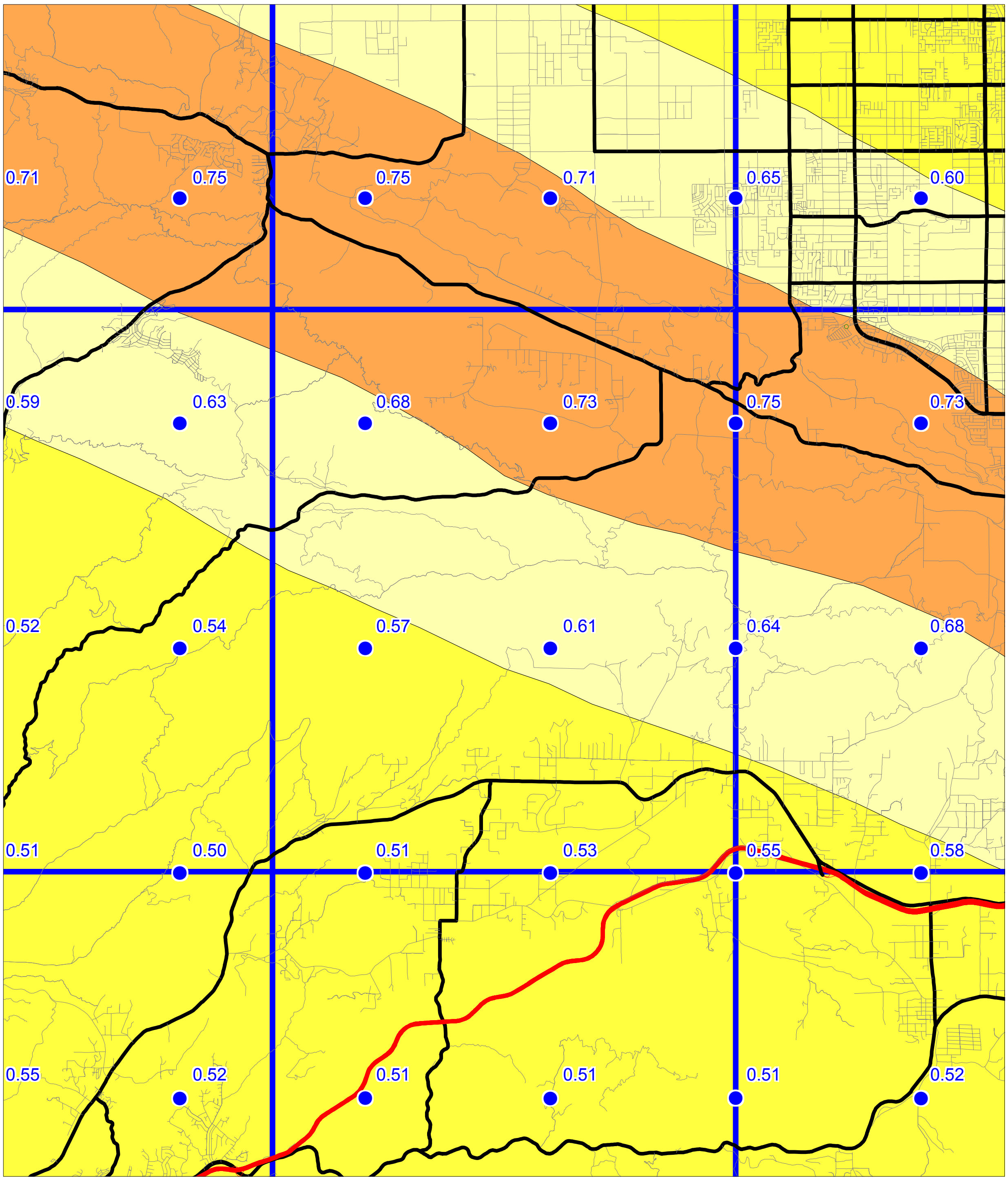
Figure 3.2

SLEEPY VALLEY 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map from GDT

0 2.5 5
Kilometers

Department of Conservation
California Geological Survey

Figure 3.3

of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10 percent probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

A preferred method of using the probabilistic seismic hazard model and the “simplified Seed-Idriss method” of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a “magnitude-weighted” ground motion (liquefaction opportunity) map that can be used directly in the calculation of the cyclic stress ratio threshold for liquefaction and for estimating the factor of safety against liquefaction (Youd and Idriss, 1997). This can provide a better estimate of liquefaction hazard than use of predominate magnitude described above, because all magnitudes contributing to the estimate are used to weight the probabilistic calculation of peak ground acceleration (Real and others, 2000). Thus, large distant earthquakes that occur less frequently but contribute *more* to the liquefaction hazard are appropriately accounted for.

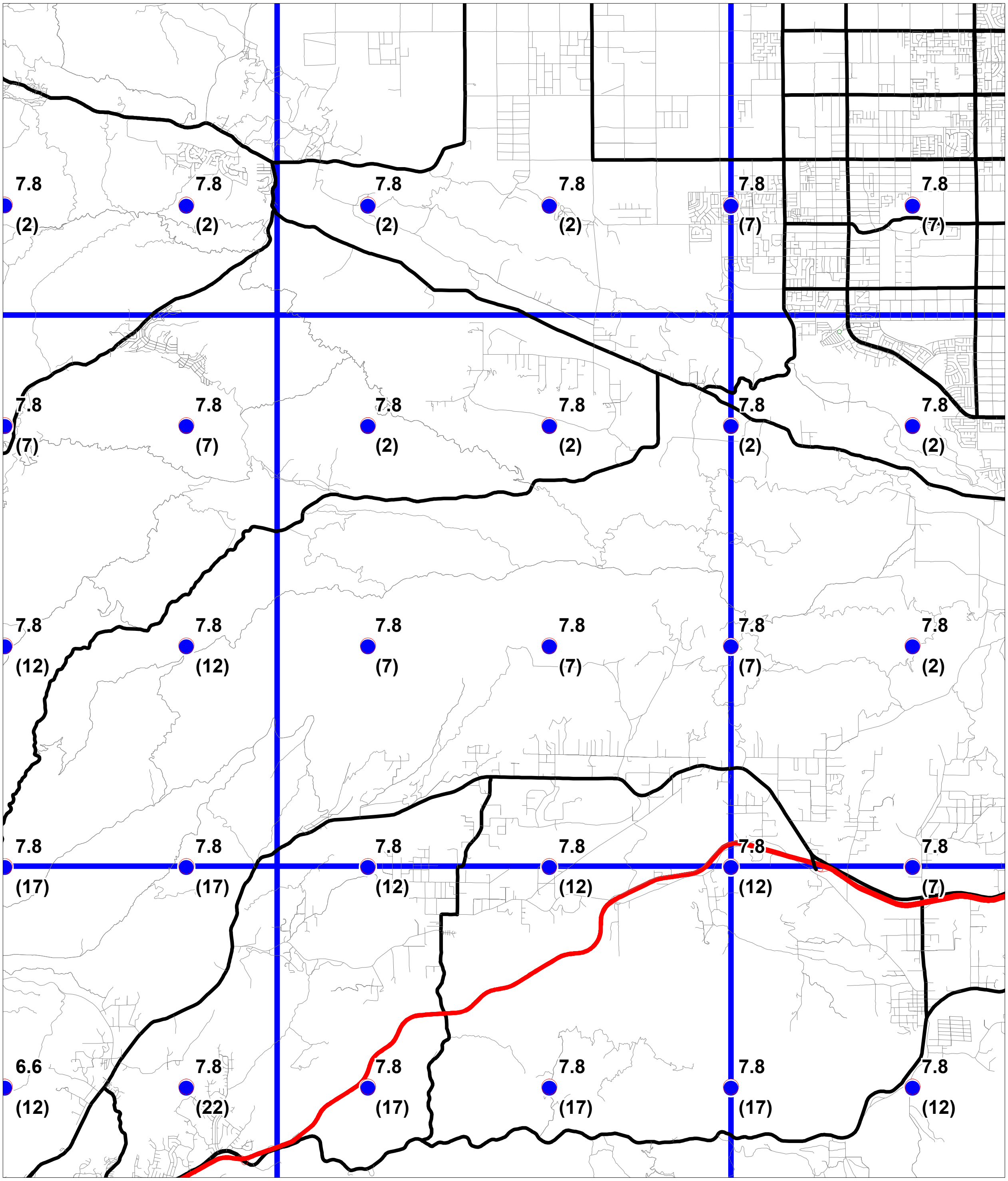
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss’ weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1) applied.

SLEEPY VALLEY 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map from GDT

0 1.5 3
Miles

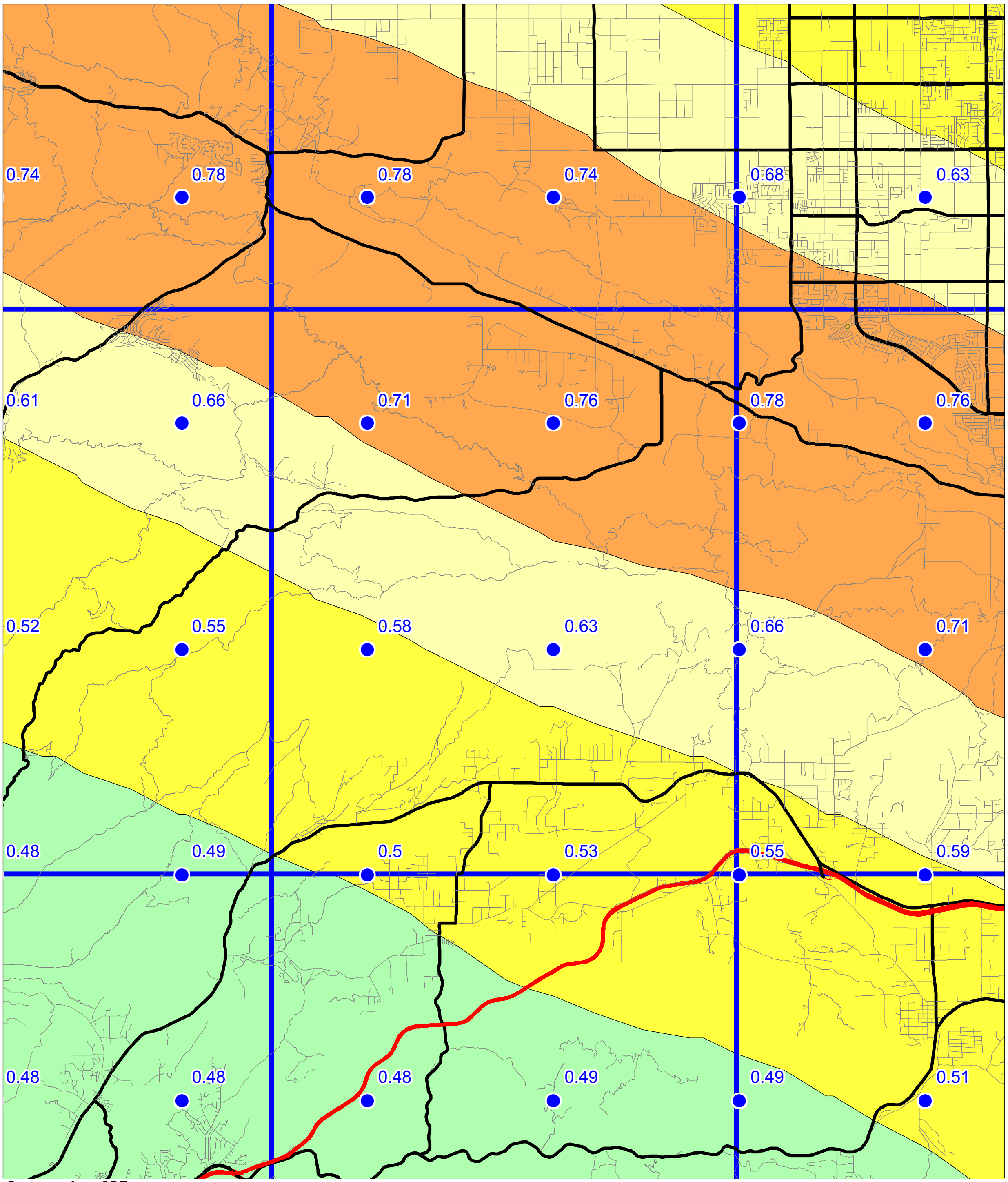
Department of Conservation
California Geological Survey
Figure 3.4

SLEEPY VALLEY 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g) FOR ALLUVIUM

1998

LIQUEFACTION OPPORTUNITY



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

Figure 3.5

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.
2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.
3. Uncertainties in the hazard values have been estimated to be about +/- 50 percent of the ground motion value at two standard deviations (Cramer and others, 1996).
4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not been previously recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.
5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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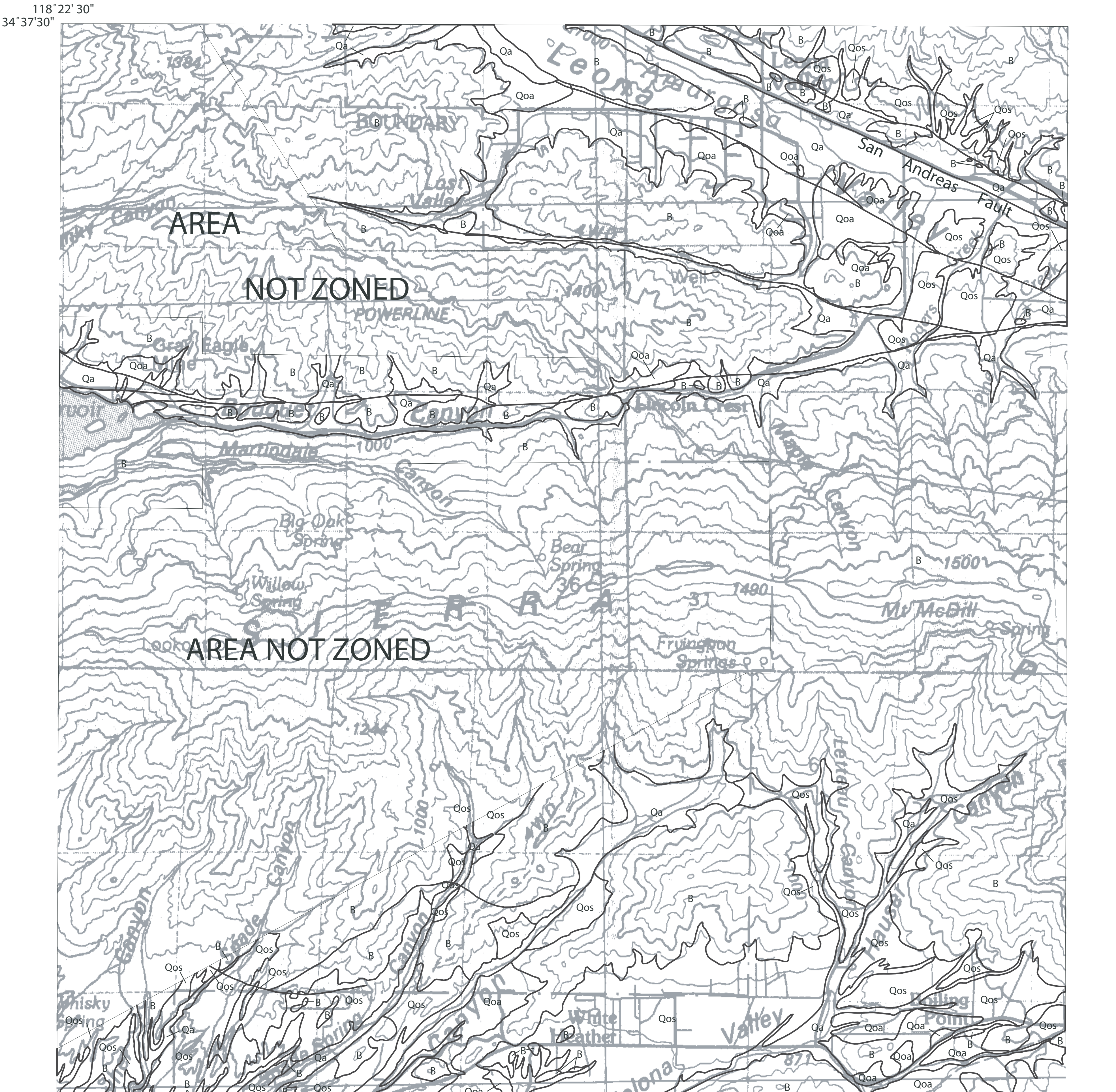


SLEEPY VALLEY QUADRANGLE

SCALE

1 MILE

7000 FEET

1 KILOMETER

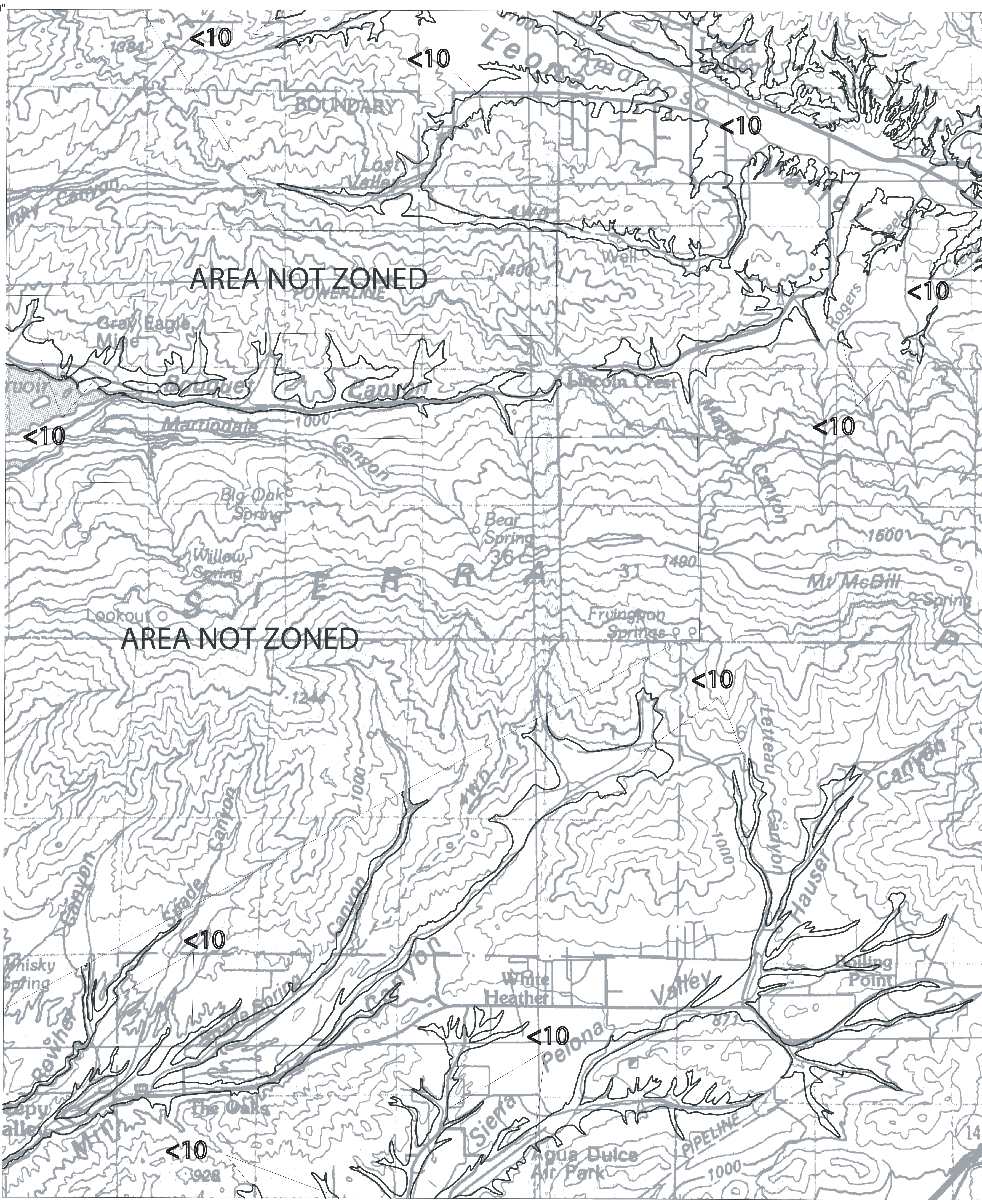
N

See "Bedrock and Surficial Geology" in Section 1 of report for descriptions of units.

B = Pre-Quaternary bedrock.

Plate 1.1 Quaternary Geologic Map of the Sleepy Valley 7.5-Minute Quadrangle, California. Modified from Dibblee (1997).

118˚22' 30"
34˚37'30"



34˚30' 00"
118˚15' 00"

Base map enlarged from U.S.G.S. 30 x 60-minute series

SLEEPY VALLEY QUADRANGLE

SCALE

1 .5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

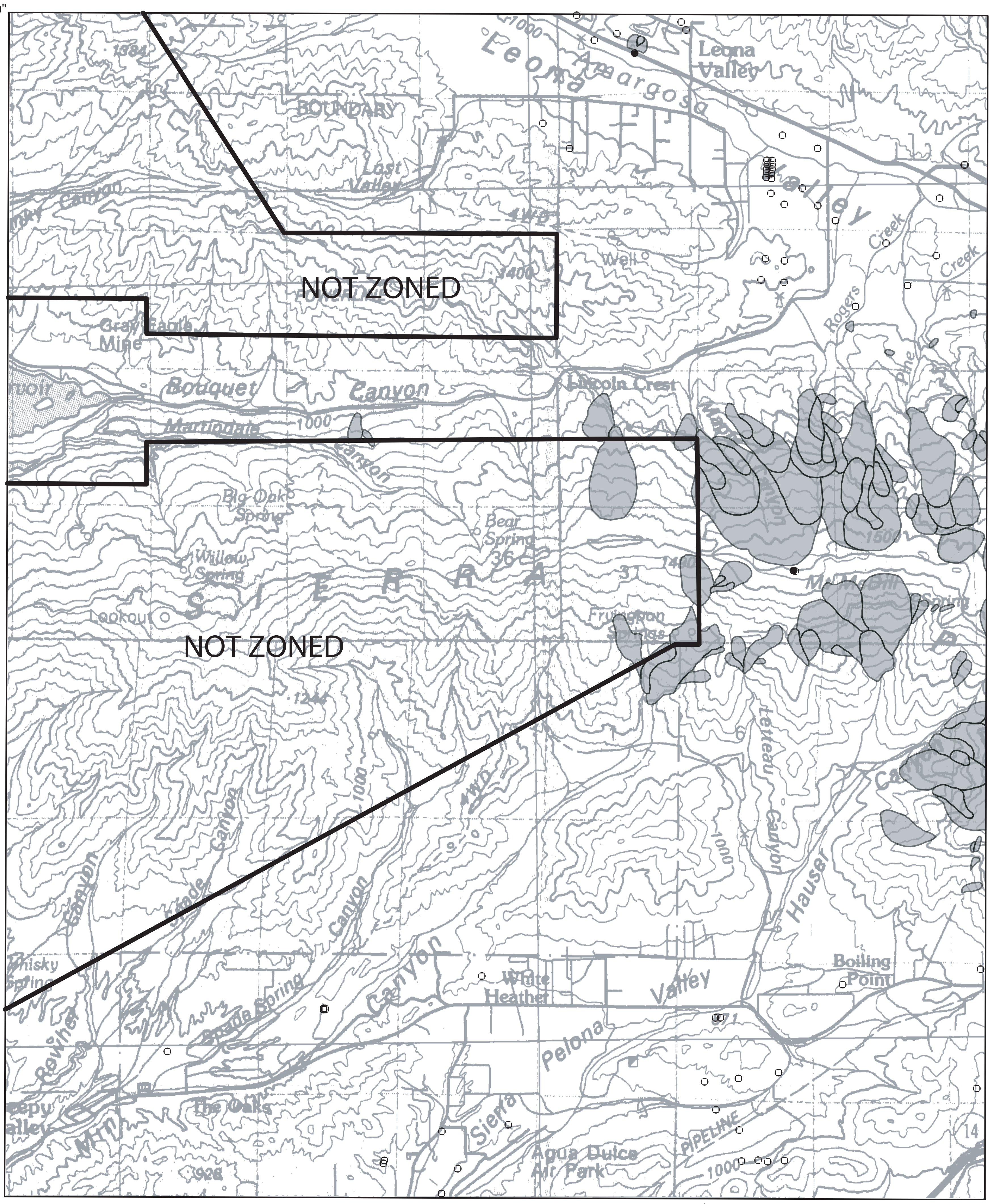
N

<10 Depth to ground water, in feet

Geotechnical borings used in liquefaction evaluation

Plate 1.2 Depth to historically high ground water, and locations of boreholes used in this study, Sleepy Valley 7.5-Minute Quadrangle, California

118˚22'30"
34˚37'30"



34˚30'
118˚15'

Base map enlarged from U.S.G.S. 30 x 60-minute series

SLEEPY VALLEY QUADRANGLE

SCALE
1 .5 0 1 MILE
1000 0 2000 4000 6000 FEET
1 .5 0 1 KILOMETER

N

Shear test sample location

Landslide

Plate 2.1 Landslide inventory, shear test sample locations, Sleepy Valley Quadrangle, California.